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An Analytical Method to Assess Spruce Beetle Impacts on White Spruce Resources, Kenai Peninsula, Alaska

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Abstract

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Forest inventory data collected in 1987 from sample plots established on the Kenai Peninsula were analyzed to provide point-in-time estimates of the trend and current status of a spruce beetle infestation. Ground plots were categorized by stage of infestation. Estimates of numbers of live and dead white spruce trees, cubic-foot volume in those trees, and areal extent of infestation were developed and are presented for each stage of infestation.

Keywords: Forest surveys, timber resources (insect damage), statistics (forest), Alaska (Kenai Peninsula).

Summary

This report presents results of a study conducted to analyze point-in-time forest inventory data in a manner allowing evaluation of current and near-term (next 5 years) spruce beetle (*Dendroctonus rufipenis* (Kirby)) infestation trends. Analytical methodology involved the development of a system to aggregate ground plots into stage-of-infestation categories. For each infestation category, estimates were developed of the number of live and dead white spruce (*Picea glauca* (Moench) Voss) trees (beetle-attacked and unattacked), the gross and net cubic-foot volume in those trees, and the acreage affected. These estimates indicate that the current infestation is larger than in the recent past (5-10 years), that the infestation will likely maintain its current magnitude, and that it may increase its magnitude in the near future.

Preface

Forest Inventory and Analysis (FIA) is a nationwide project of the USDA Forest Service authorized by the Forest and Rangeland Renewable Resources Research Act of 1978. Work units of the project, located at Forest Service Experiment Stations, conduct forest resource inventories throughout the 50 States. The Pacific Northwest Research Station at Portland, Oregon, has responsibility for forest inventories in Alaska, California, Hawaii, Oregon, Washington, and the American Pacific Trust Islands.

Contents

Introduction

The study area is on the Kenai Peninsula of south-central Alaska, between 148° 30' and 152° 00' west longitude and between 59° 05' and 61° 05' north latitude (fig. 1). The peninsula is about 5.2 million acres in size. Forest land makes up about 1.9 million acres (van Hees and Larson, 1991). For several decades, the forest resource—white spruce (*Picea glauca* (Moench) Voss) and Lutz spruce (*Picea* x *Lutzii* Little), in particular—has been subjected to damage by the spruce beetle (*Dendroctonus rufipenis* (Kirby)). This study was conducted to develop a methodology for examining forest inventory data that would allow estimation of current status and potential near-term (next 5 years) trends of the beetle infestation.

The focus of this study is on the white spruce resource of the Kenai Peninsula. Throughout this report, unless otherwise stated, any reference to trees means white spruce trees.

Methods

Inventory Procedures

The inventory design was based on a double sampling (two-phase) technique (Bickford 1952). In the first phase of the sample, 5,597 photo points were systematically distributed over 1:60,000-scale aerial photographs and then interpreted. Each photo point was classified into one of four land classes: timberland (land at least 16.7 percent stocked by forest trees of any size, or formerly having such tree cover [forest land] and producing or capable of producing at least 20 cubic feet per acre per year of industrial wood at culmination of mean annual increment [MAI]); other forest land (forest land producing less than 20 cubic feet MAI); nonforest (land not qualifying as forest land); and water (streams, sloughs, estuaries, and canals greater than 120 feet wide and lakes, reservoirs, and ponds greater than 1 acre in area).

From the 5,597 photo points, a random sample of 1,216 plots was selected for further examination and possible ground visitation. All timberland locations in the random sample were visited on the ground. Other forest land locations in the random sample were re-examined on the aerial photos for possible misinterpretation of potential timberland locations. All other forest land points possibly misinterpreted were selected and added to the ground visitation list. One hundred and eighteen timberland photo points along with 12 photo points initially identified as other forest land were ground visited. No photo points initially classified as water or nonforest were selected for ground visitation.

Plot Aggregation for Analysis

A system was developed to classify ground plots into infestation stages for analysis. The ground plots were classed as either infested or uninfested by the presence or absence of beetle-attacked trees. Tree history (live, dead less than 5 years, and dead more than 5 years) of attacked trees (if any) on the plots provided information to further categorize plots according to stage of infestation as follows:

Uninfested—No live or dead tree on the plot showed any indication of beetle attack or injury.

Potential infestation—Plots on which only live trees showed signs of beetle attack, plus plots on which live trees were attacked and trees dead more than 5 years showed signs of attack. This latter group of plots represents areas where there was potential reinfestation of an area attacked more than 5 years before the date of inventory.

Ongoing infestation—Plots on which live trees and trees dead less than 5 years showed signs of beetle attack.

Past infestation—Plots on which only dead trees showed signs of beetle attack.

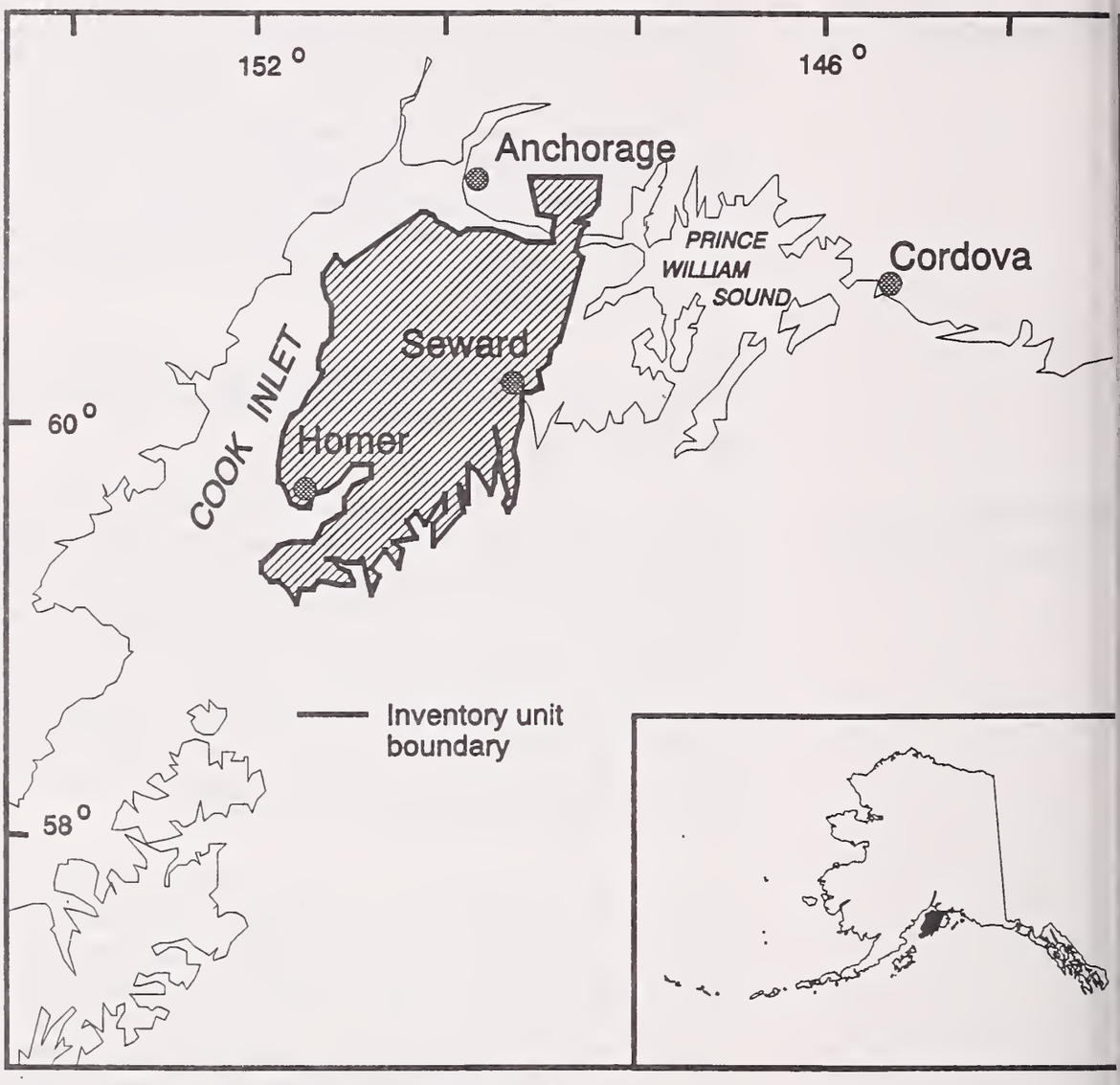

Figure 1—Study area, Kenai Peninsula, Alaska, 1987.

Data

Plot data—Three classes of ground plots were used in this study: those that were interpreted on the photos as timberland and were found to be such on the ground; those photo-interpreted as timberland but found to be other forest land when visited; and those initially photo-interpreted as other forest land, subsequently determined to be potential timberland, and found to be either timberland or other forest land when visited. From the photo sample, 130 plots were selected for ground visitation; 129 had trees on them and one was classed as nonforest after ground visitation. Table 1 (see appendix) summarizes, by stage of infestation, the initial, photo-interpreted distribution and the final distribution. The plot attributes used in this study were the area expansion factor (stratum area/number of plots in stratum) and land class.

Tree data—In the south-central region of Alaska, including the Kenai Peninsula, white spruce and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) cross-pollinate to form the hybrid Lutz spruce. Identification of Lutz spruce from features apparent to the unaided eye is difficult. Also, on most of the Kenai Peninsula, Lutz spruce is more similar to white spruce than to Sitka spruce in terms of habitat; it is usually found growing with tree species that are common associates of the white spruce forest type, such as paper birch (*Betula Papyrifera* Marsh.). For these reasons, observations from Lutz spruce trees were combined with those from white spruce trees for this study.

All white spruce trees tallied on the ground plots, regardless of health, vigor, or age, were included in this study. Tree data used for this study were tree history, beetle attack indication (attacked versus unattacked), form and volume defect, height, and diameter at breast height (d.b.h.). Gross tree volumes were computed from volume equations developed by Larson and Winterberger (1988). Net volumes were computed by deducting defect amounts from gross volume. In this study, trees were considered live if they were such at the time of measurement, even though they may have been fatally infested with beetles. Thus, both live and dead trees could have beetle attack, though to a forest resource manager, a live, attacked tree may essentially be a dead tree.

Results

Summation of plot area-expansion factors by stage of infestation produced estimates of acres affected by the spruce bark beetle along with estimates of uninfested areas (table 2). Nearly 48 percent (231 thousand acres) of the timberland area and 46 percent (114 thousand acres) of the other forest land area represented by visited ground plots has been affected by beetle activity. Because the focus of the inventory was on the timberland component, not all other forest land plots were ground visited. Estimates of other forest land affected by beetle activity are incomplete in that they are representative only of the "higher" site portion of the other forest land component. Therefore, estimates of totals likely are conservatively biased.

Estimated numbers of live and dead trees, both beetle-attacked and unattacked, by 2-inch d.b.h. class are presented numerically in tables 3 and 4 and graphically in figures 2 and 3. Of an estimated 87 million live white spruce trees (4 inches d.b.h. and larger) about 43 million are in areas that have had beetle activity. About 2.5 million (6 percent) of the live trees on affected acres have some degree of beetle activity evident. There are an estimated 13 million dead spruce trees, of which about 8 million are in areas with beetle activity. Nearly 63 percent (5 million trees) of the dead trees on affected areas have evidence of beetle activity.

Estimated gross and net cubic-foot volumes in trees 5 inches d.b.h. and larger are presented in tables 5 through 8. Gross volumes are graphically presented in figures 4 and 5. Roughly 45 percent (349,863 thousand cubic feet) of the estimated total (770,919 thousand cubic feet) net live-tree volume is in areas affected by the beetle. About 7 percent (24,591 thousand cubic feet) of the live-tree volume on beetle-affected areas is in trees with indication of beetle activity. Cubic volume in dead trees shows significant beetle impacts. There are about 25,714 thousand cubic feet in dead white spruce trees. Eighty-three percent (21,379 thousand cubic feet) is in beetle-affected areas; of this, 17,019 thousand cubic feet (80 percent) is in trees that suffered beetle attack.

From these estimates, it appears that the infestation, over the whole Kenai Peninsula, has increased substantially in recent years and likely will maintain, if not increase, its magnitude.

The assertion that the infestation has increased in recent years derives from three observations. First, that of all dead trees, the number (table 4) and percentage (table 9) affected by beetle attack increased for most d.b.h. classes when estimates of ongoing-infestation are compared with estimates of past infestation. Although the 4- and 6-inch diameter classes show lower relative numbers of trees attacked in areas with ongoing infestations versus areas where the infestation passed, most succeeding diameter classes show higher relative numbers attacked. Second, the estimated area of land affected by ongoing infestations (infested less than 5 years), 120,983 acres, is almost

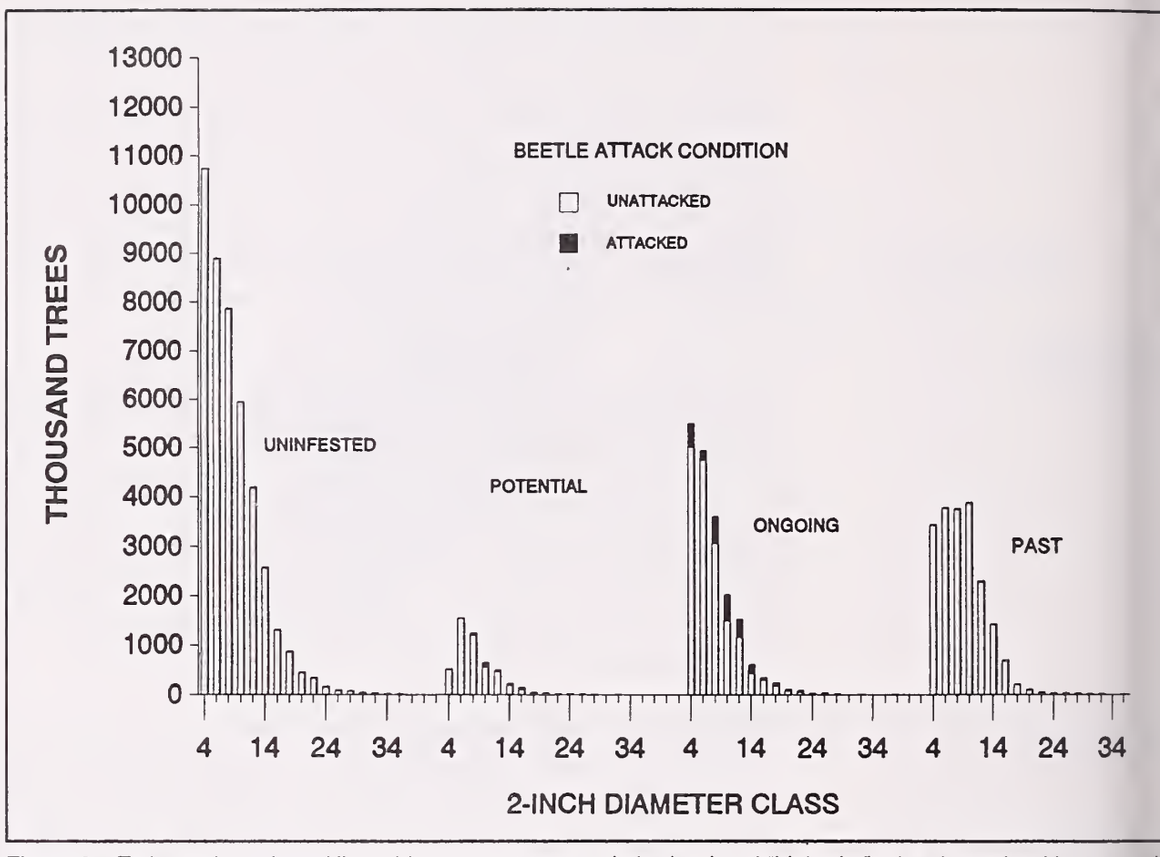

Figure 2—Estimated number of live white spruce trees on timberland and "high-site" other forest land by stage of infestation, 2-inch diameter class, and condition of beetle attack, Kenai Peninsula, Alaska, 1987.

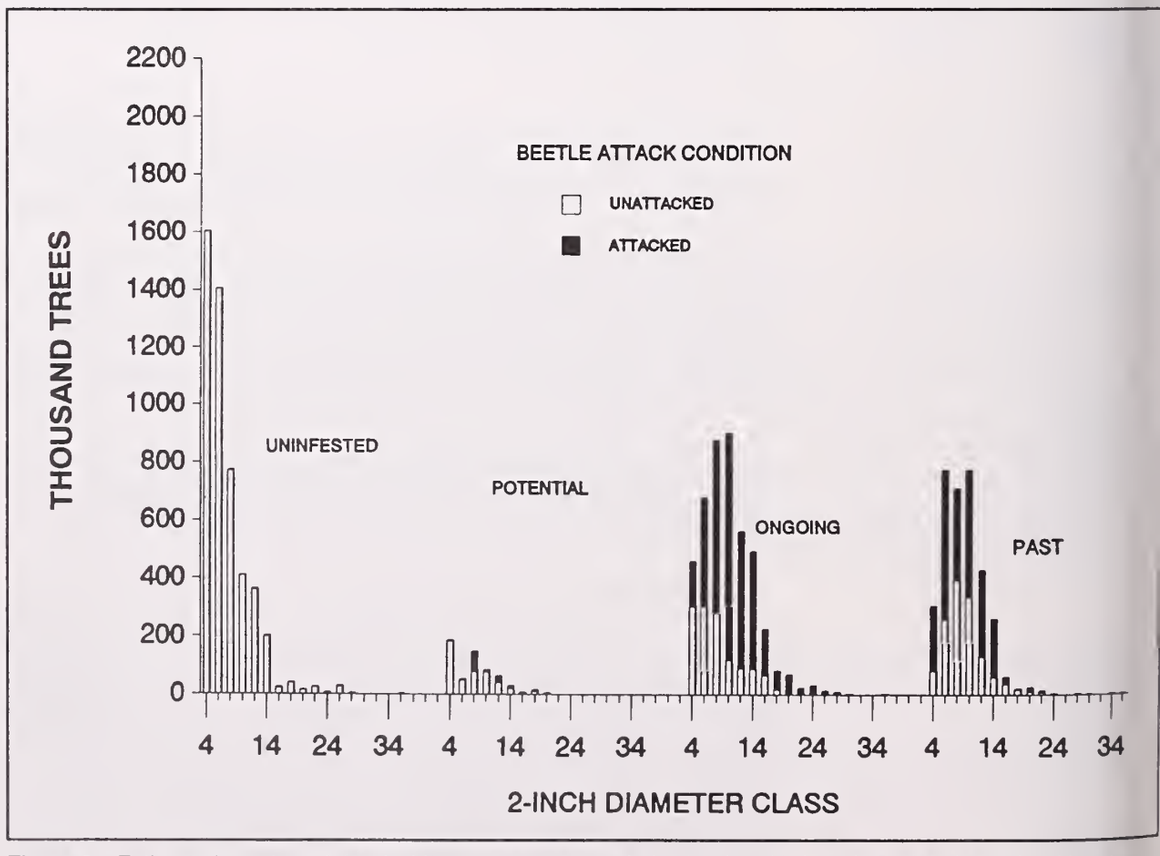

Figure 3—Estimated number of dead white spruce trees on timberland and "high-site" other forest land by stage of infestation, 2-inch diameter class, and condition of beetle attack, Kenai Peninsula, Alaska, 1987.

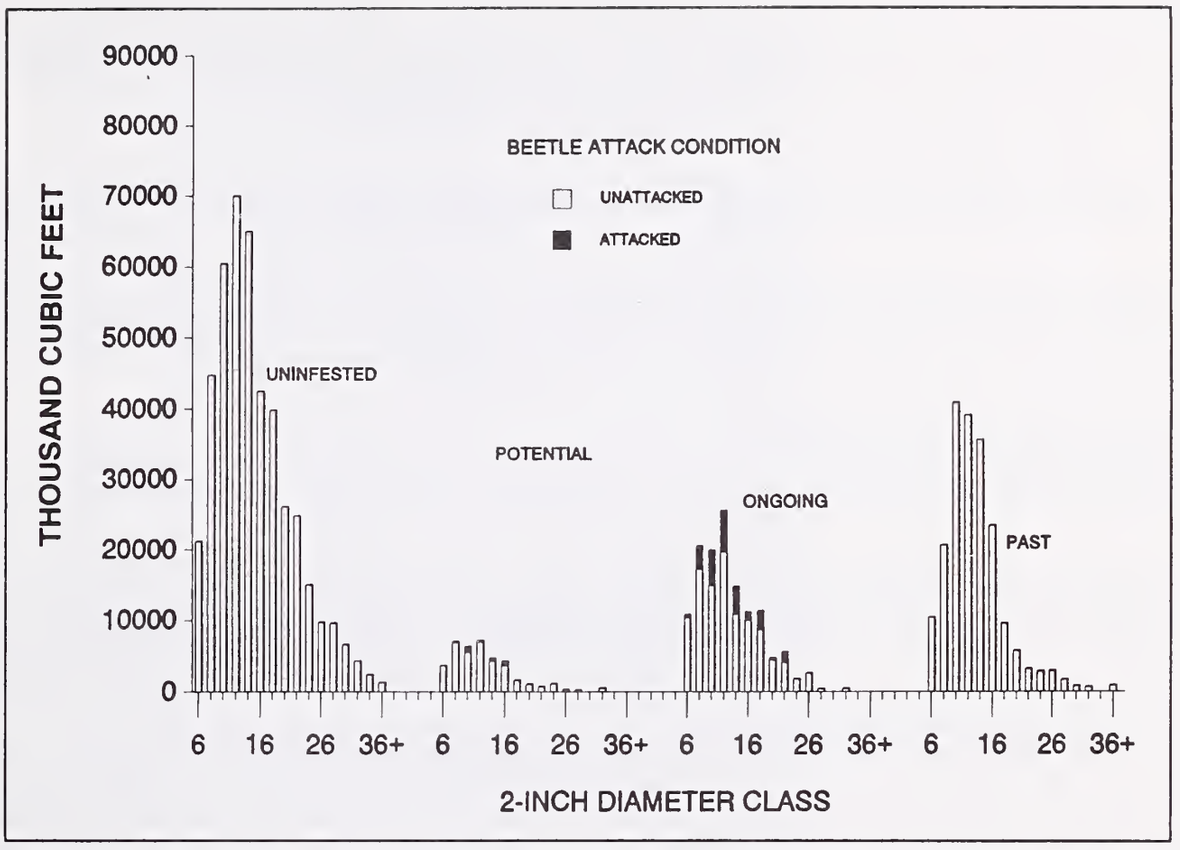

Figure 4—Estimated gross cubic-foot volume in live white spruce trees on timberland and "high-site" other forest land by stage of infestation, 2-inch diameter class, and condition of beetle attack, Kenai Peninsula, Alaska, 1987.

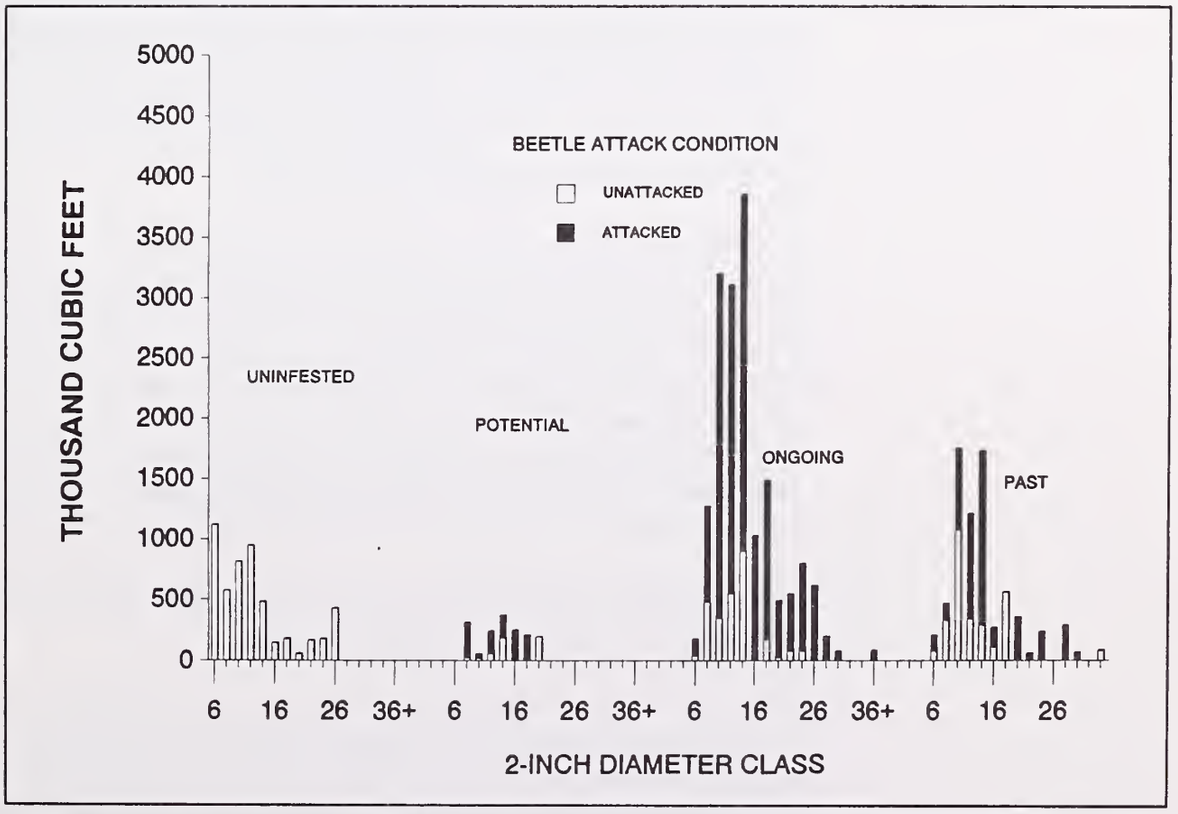

Figure 5—Estimated gross cubic-foot volume in dead white spruce trees on timberland and "high-site" other forest land by stage of infestation, 2-inch diameter class, and condition of beetle attack, Kenai Peninsula, Alaska, 1987.

the same as the estimated area where infestations have run their course (142,619 acres). Third, half of the current live-tree resource (both attacked and unattacked) is within beetle-attacked areas (table 3).

The possibility that the infestation likely will maintain and perhaps increase in magnitude is based on two observations. First, the residual, live-tree resource on areas where the infestation has passed is larger than the live-tree resource in either areas of ongoing infestation or areas of potential infestation. Second, the estimated area of potential infestation (80,759 acres) is similar in magnitude to the area in currently ongoing infestations (120,983 acres). This suggests that at least for the near term (next 5 years), the infestation can maintain its current magnitude.

The import of these two observations to the potential for an increase in the magnitude of infestation is that stands once susceptible often remain susceptible to reinfestation. After an initial beetle attack, stand structure is altered, in that diameters of remaining live trees tend to be smaller. Although the result may be release of the smaller trees, the increase in diameter growth is not always substantial enough to overcome subsequent beetle attack. According to Hard and others (1983), reduced radial growth of spruce trees is a factor in increased incidence of beetle attack leading to tree mortality.

The existence of (1) a previously attacked and currently susceptible resource and (2) an area of potential infestation similar in magnitude to the area of currently ongoing infestations are strong indicators that the overall infestation could increase.

Conclusions

Estimates presented in this report were developed from data collected in 1987. Projections of infestation trends are relevant for the 5-year period, 1988 to 1992. As of the date of completion of this study (January 1991), the infestation has indeed expanded. Spruce beetle populations were noted as static in 1988 and declining in 1989 (U.S. Department of Agriculture 1990a). Dramatic increases were noted in 1990 (U.S. Department of Agriculture 1990b), thereby providing some measure of validation for the analytical process developed in this study.

The focus of the inventory that provided the data for this study was on the timberland component of the forest resource. By including all plots where trees were found, the focus of this study was effectively broadened to include higher site other forest land (forest land producing, or capable of producing, 15 to 19 cubic feet at culmination of MAI). Also, the inventory was designed to estimate timberland area with a precision of ±3 percent per million acres and net cubic volume on those acres with a precision of ±10 percent per billion cubic feet at the 68-percent confidence level. Standard errors for estimates of breakdowns of these totals are larger. Users of the data presented in tables or graphs in this report must be aware of this consideration.

The plot-based nature of the estimates presented in this report precludes on-the-ground identification of specific infestation pockets.

Presentation of gross and net cubic-foot volume estimates is for reader understanding of the overall magnitude of quantities affected by the beetle infestation. These estimates, because they include trees of all sizes and qualities, in many different locations, are not to be interpreted as being estimates of recoverable, usable timber resources.

Metric Equivalents

1 inch = 2.54 centimeters
1 acre = 0.4047 hectare
1 cubic foot = 0.0283 cubic meter
1 cubic foot per acre = 0.07 cubic meter per hectare

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Appendix

Table 1—Distribution of number of ground plots by initial photo-interpreted (PI) land class, final ground land class, and stage of infestation, Kenai Peninsula, Alaska, 1987

Stage of infestation	Total number of plots	PI land class		Ground land class	
		Timberland	Other forest land	Timberland	Other forest land
	Number of plots				
Uninfested	62	56	6	41	21
Potential	14	11	3	11	3
Ongoing	26	24	2	17	9
Past	27	26	1	18	9
Total	129	117	12	87	42

Table 2—Estimated areas of timberland and other forest land by stage of infestation, Kenai Peninsula, Alaska, 1987

Stage of infestation	Timberland	Other forest land	Total
	Acres		
Potential	61,430	19,329	80,759
Ongoing	76,987	43,996	120,983
Past[a]	92,359	50,259	142,619
Total affected area	230,776	113,584	344,360
Uninfested	250,880	131,912	382,792
All areas	481,655	245,496[b]	727,151

Totals may be off due to rounding.

[a] Includes areas where infestation ended more than 5 years before the date of inventory (1987).
[b] An estimated additional 1,181,651 acres of other forest land are represented by locations not visited on the ground.

Table 3—Estimated number of live white spruce trees on timberland and "high-site" other forest land by 2-inch diameter class, stage of infestation, and state of beetle attack, Kenai Peninsula, Alaska, 1987

Diameter class	Stage of infestation					
		Potential		Ongoing		
	Uninfested	U[a]	A[b]	U	A	Past[c]
	Thousand trees					
4	10,735	514	--	5,011	468	3,432
6	8,883	1,550	--	4,752	177	3,769
8	7,856	1,207	30	3,062	527	3,745
10	5,940	561	81	1,493	522	3,872
12	4,177	470	15	1,157	361	2,295
14	2,569	193	21	432	167	1,422
16	1,305	116	21	296	37	689
18	861	41	--	178	55	206
20	438	21	--	85	6	97
22	332	12	--	58	16	42
24	157	8	--	20	--	28
26	81	3	--	23	--	27
28	68	2	--	3	--	13
30	37	--	--	--	--	4
32	23	2	--	2	--	4
34	11	--	--	--	--	--
36+	4	--	--	--	--	2
Total	43,478	4,700	169	16,569	2,337	19,650

Totals may be off due to rounding.
-- = no data were collected.

[a] U = unattacked trees.
[b] A = attacked trees.
[c] All trees unattacked.

Table 4—Estimated number of dead white spruce trees on timberland and "high-site" other forest land by 2-inch diameter class, stage of infestation, and state of beetle attack, Kenai Peninsula, Alaska, 1987

Diameter class	Stage of infestation						
		Potential		Ongoing		Past	
	Uninfested	U[a]	A[b]	U	A	U	A
	Thousand trees						
4	1,603	185	--	302	157	83	222
6	1,404	51	--	302	376	258	514
8	772	77	70	279	597	393	316
10	409	78	4	119	782	334	439
12	361	40	23	91	471	131	297
14	199	21	9	89	405	60	200
16	23	--	6	67	158	38	22
18	40	10	5	17	64	19	--
20	15	4	--	3	65	10	15
22	25	--	--	6	16	9	4
24	7	--	--	4	27	--	3
26	27	--	--	--	13	--	--
28	3	--	--	--	8	--	3
30	--	--	--	--	2	--	2
32	--	--	--	--	--	--	--
34	--	--	--	--	--	2	--
36+	1	--	--	--	2	--	--
Total	4,890	464	117	1,280	3,143	1,338	2,037

Totals may be off due to rounding.
-- = no data were collected.

[a] U = unattacked trees.
[b] A = attacked trees.

Table 5—Estimated gross cubic-foot volume of live white spruce trees on timberland and "high-site" other forest land by 2-inch diameter class, stage of infestation, and state of beetle attack, Kenai Peninsula, Alaska, 1987

Diameter class	Stage of infestation					
		Potential		Ongoing		
	Uninfested	U[a]	A[b]	U	A	Past[c]
	Thousand cubic feet					
6	21,163	3,664	--	10,311	428	10,386
8	44,733	6,821	190	17,188	3,260	20,559
10	60,432	5,498	853	14,833	5,028	40,741
12	70,003	6,927	225	19,641	5,846	39,004
14	64,971	4,255	418	10,849	3,800	35,504
16	42,480	3,681	621	9,961	1,168	23,334
18	39,820	1,600	--	8,617	2,625	9,526
20	26,095	1,060	--	4,386	338	5,706
22	24,778	710	--	4,019	1,454	3,180
24	15,008	1,103	--	1,777	--	2,834
26	9,751	323	--	2,595	--	2,887
28	9,582	232	--	411	--	1,656
30	6,615	--	--	--	--	769
32	4,301	526	--	431	--	664
34	2,402	--	--	--	--	--
36+	1,302	--	--	--	--	883
Total	443,436	36,402	2,307	105,021	23,946	197,632

Totals may be off due to rounding.
-- = no data were collected.

[a] U = unattacked trees.
[b] A = attacked trees.
[c] All trees unattacked.

Table 6—Estimated gross cubic-foot volume of dead white spruce trees on timberland and "high-site" other forest land by 2-inch diameter class, stage of infestation, and state of beetle attack, Kenai Peninsula, Alaska, 1987

Diameter class	Stage of infestation						
		Potential		Ongoing		Past	
	Uninfested	U[a]	A[b]	U	A	U	A
	Thousand cubic feet						
6	1,118	0	--	41	132	76	128
8	573	24	285	479	790	329	135
10	812	15	42	343	2,854	1,074	672
12	947	54	187	548	2,560	337	873
14	479	183	188	895	2,955	287	1,443
16	145	--	248	0	1,027	106	160
18	176	0	207	169	1,316	560	--
20	55	194	--	23	467	0	356
22	164	--	--	77	469	0	60
24	176	--	--	76	720	--	236
26	426	--	--	--	614	--	--
28	0	--	--	--	196	--	286
30	--	--	--	--	75	--	69
32	--	--	--	--	--	--	--
34	--	--	--	--	--	81	--
36+	--	--	--	--	81	--	--
Total	5,071	469	1,157	2,651	14,255	2,850	4,419

Totals may be off due to rounding.
-- = no data were collected.

[a] U = unattacked trees.
[b] A = attacked trees.

Table 7—Estimated net cubic-foot volume of live white spruce trees on timberland and "high-site" other forest land by 2-inch diameter class, stage of infestation, and state of beetle attack, Kenai Peninsula, Alaska, 1987

Diameter class	Stage of infestation					
		Potential		Ongoing		
	Uninfested	U[a]	A[b]	U	A	Past[c]
	Thousand cubic feet					
6	21,028	3,593	--	10,232	428	10,205
8	43,872	6,661	189	16,991	3,168	20,243
10	59,341	5,377	843	14,245	4,881	39,448
12	67,975	6,641	222	18,922	5,211	37,854
14	62,572	4,120	382	10,411	3,256	34,192
16	39,072	3,462	594	9,475	957	22,130
18	37,392	1,541	--	8,234	2,544	8,917
20	24,227	999	--	3,866	259	5,468
22	22,398	627	--	3,668	1,309	2,972
24	13,475	1,051	--	1,625	--	2,425
26	8,939	306	--	2,381	--	2,665
28	8,746	203	--	387	--	1,252
30	5,693	--	--	--	--	720
32	3,045	490	--	401	--	441
34	2,126	--	--	--	--	--
36+	1,155	--	--	--	--	778
Total	421,056	35,071	2,230	100,838	22,013	189,711

Totals may be off due to rounding.
-- = no data were collected.

[a] U = unattacked trees.
[b] A = attacked trees.
[c] All trees unattacked.

Table 8—Estimated net cubic-foot volume of dead white spruce trees on timberland and "high-site" other forest land by 2-inch diameter class, stage of infestation, and state of beetle attack, Kenai Peninsula, Alaska,1987

Diameter class	Stage of infestation						
		Potential		Ongoing		Past	
	Uninfested	U[a]	A[b]	U	A	U	A
	Thousand cubic feet						
6	976	0	--	37	132	27	73
8	542	24	274	458	725	254	110
10	724	11	29	218	2,788	775	497
12	800	27	175	481	2,295	182	731
14	391	179	184	732	2,516	236	762
16	114	--	192	0	838	82	156
18	144	0	180	163	1,200	261	--
20	42	53	--	17	409	0	279
22	100	--	--	55	424	0	39
24	97	--	--	35	660	--	201
26	405	--	--	--	538	--	--
28	0	--	--	--	162	--	270
30	--	--	--	--	62	--	55
32	--	--	--	--	--	--	--
34	--	--	--	--	--	55	--
36+	--	--	--	--	63	--	--
Total	4,335	293	1,034	2,195	12,812	1,872	3,173

Totals may be off due to rounding.
-- = no data were collected.

[a] U = unattacked trees.
[b] A = attacked trees.

Table 9—Percentage of estimated number of dead white spruce trees on timberland and "high-site" other forest land showing evidence of beetle attack, by stage of infestation and 2-inch diameter class, Kenai Peninsula, Alaska, 1987

Diameter class	Stage of infestation		
	Potential	Ongoing	Past
	Percent		
4	0	34.2	72.8
6	0	55.5	66.6
8	47.5	68.1	44.5
10	4.7	86.7	56.8
12	37.3	83.8	69.3
14	28.8	81.9	76.9
16	100.0	70.3	36.7
18	32.9	20.9	0
20	0	95.9	58.4
22	--	71.4	32.8
24	--	88.3	100.0
26	--	0	0
28	--	100.0	100.0
30	--	0	100.0
32	--	--	--
34	--	--	
36+	--	0	--
All classes	20.1	70.7	60.4

-- = no data were collected.

van Hees, Willem W.S. 1992. An analytical method to assess spruce beetle impacts on white spruce resources, Kenai Peninsula, Alaska. Res. Pap. PNW-RP-446. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 15 p.

Forest inventory data collected in 1987 from sample plots established on the Kenai Peninsula were analyzed to provide point-in-time estimates of the trend and current status of a spruce beetle infestation. Ground plots were categorized by stage of infestation. Estimates of numbers of live and dead white spruce trees, cubic-foot volume in those trees, and areal extent of infestation were developed and are presented for each stage of infestation.

Keywords: Forest surveys, timber resources (insect damage), statistics (forest), Alaska (Kenai Peninsula).

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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